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The Onset of Galactic Winds in Early-Type Galaxies

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Einstein x-ray observations have shown that bright elliptical galaxies contain extensive coronae of hot ($T \sim 10^7\text{K}$) gas. Prior to the Einstein observations, it was generally believed that early-type galaxies (ellipticals and S0's) contained little gas or dust. The discovery from Einstein observations that bright early-type galaxies, as a class, contain up to several $10^{10} M_{\odot}$ of hot gas (Forman, Jones and Tucker 1985) both demonstrated that these galaxies contained a substantial interstellar medium and provided a tool for measuring the total mass of these systems. While the x-ray emitting coronae seen in the Einstein images account for the bulk of the mass shed by the evolving stars, sensitive observations primarily in the optical and the infrared have shown that the interstellar medium in early-type galaxies is complex with components (gas and dust) at widely differing temperatures (e.g. Jura 1986, Jura et al. 1987, DeMoulin-Ulrich et al. 1984, Phillips et al. 1984)

In our initial x-ray survey (Forman, Jones and Tucker 1985), we showed that, if the hot coronae around luminous early-type galaxies were not in hydrostatic equilibrium, then the replenishment rates of the gas would have to be nearly 100 times higher than expected from the mass loss by the known stellar populations. Therefore, we concluded that these galaxies do not presently drive galactic winds. It is now generally agreed that a massive dark halo is required to gravitationally bind these hot coronae to the underlying galaxies (Forman, Jones, and Tucker 1985, Fabian et al. 1986, Mathews and Loewenstein 1986, Sarazin and White 1988; see Trimble 1987 for a review).

The status of the hot gas in lower luminosity (and hence lower mass) galaxies is less clear. Calculations show that, for a given supernova rate, a critical galaxy luminosity (mass) exists below which the gas cannot be gravitationally confined and a galactic wind is predicted to be effective in expelling gas from the galaxy (Loewenstein and Mathews 1987; David et al. 1988). Thus, galaxies which fall below a certain mass are expected to drive winds and should contain little or no hot gas. The critical galaxy luminosity which defines the transition from hydrostatic atmospheres to galactic winds depends on the type I supernova rate.

We report on a program using Einstein X-ray observations of the x-ray spectra and surface brightness profiles (or extents) of a large sample of early-type (elliptical and S0) galaxies for which our goal is to determine the critical optical luminosity

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for which galactic winds are important. For galaxies in which the x-ray emission is dominated by hydrostatic coronae, the x-ray spectra will be relatively soft (characterized by a temperature of $\sim 10^7\text{K}$), while for galaxies with a galactic wind, the emission will be dominated by the spectrally harder discrete sources (since the x-ray emission from the wind is essentially negligible). Although galaxies in the transition region, those having subsonic or partial winds, may have spectra that are comparable to those with hydrostatic atmospheres, they are predicted to have flatter x-ray surface brightness profiles. Thus, with a combination of surface brightness profiles and x-ray spectroscopy, we should be able to determine the critical luminosity separating galaxies with winds from those with hydrostatic gaseous coronae. Gas temperatures have so far been published for only nine early-type galaxies (eight in Forman, Jones, and Tucker, 1985 and one additional galaxy spectrum in Trinchieri et al. 1986). These nine published spectra are all for quite luminous galaxies. In our new sample of 180 galaxies, there are 28 early type galaxies with sufficient counts to obtain a spectrum with the Einstein IPC (these galaxies are marked in Figure 1). This sample more than doubles the total number of early-type galaxies in earlier compilations (Forman, Jones, and Tucker 1985; Canizares et al. 1987). The new new spectral observations will help determine the critical optical luminosity for the onset of galactic winds which is important for understanding the chemical evolution of galaxies and of the intergalactic medium. The implications of galactic winds for the heavy element enrichment and energy content of the intracluster medium will be discussed.

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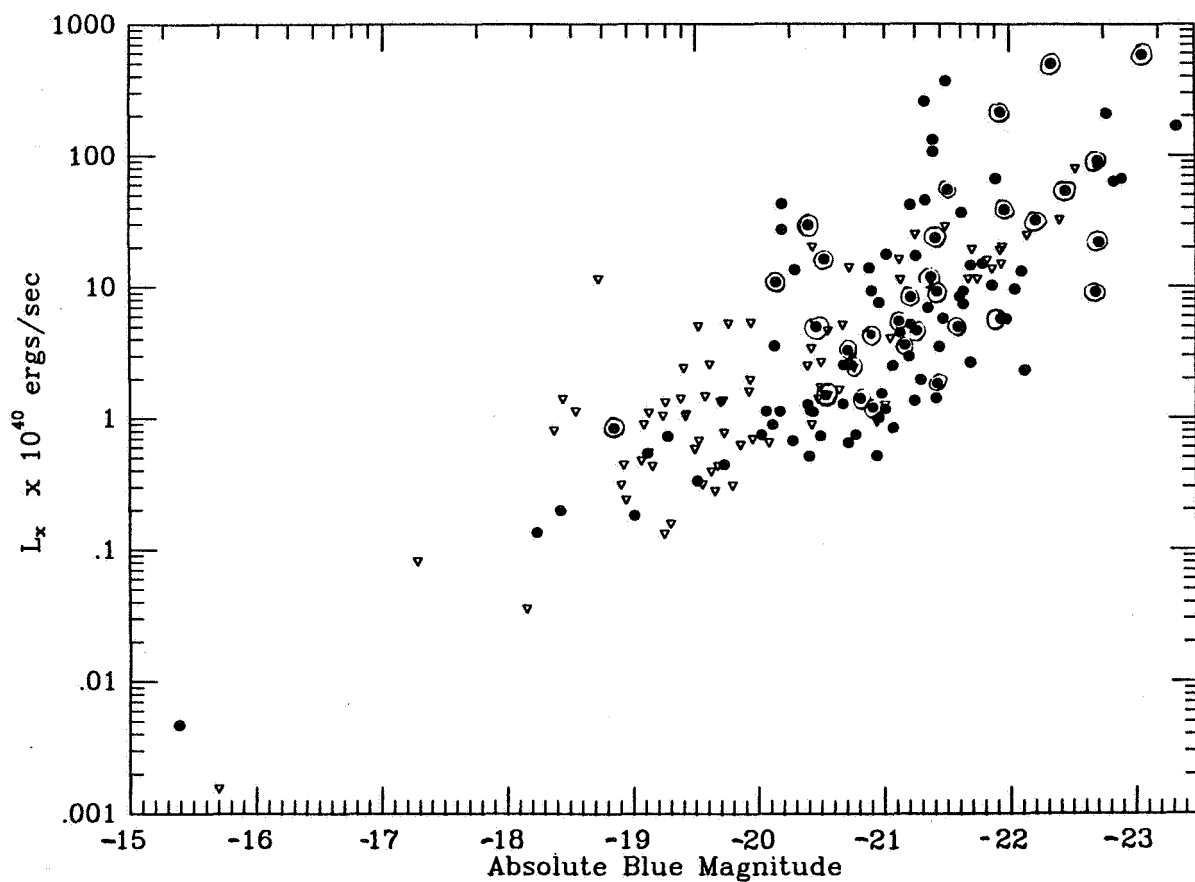


Figure 1 shows the correlation, for nearly 180 early type galaxies, of x-ray with optical luminosity. The solid circles are detections and the open triangles represent upper limits. Galaxies whose x-ray spectra can be determined are denoted with a second, open circle.